The effect of flood conditions on the groundwater quality of a borehole at Baroda near Cradock, Eastern Cape Province

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Abstract

Analyses of groundwater samples taken at various time intervals over a period of several months from a single borehole, proved that significant changes in the inorganic quality occurred after periods of extreme flood conditions. The main changes which occurred, one and a half months after devastating floods, were an increase in the Cl^-, $SO_4^=$ and Na^+ concentration, whilst only a slight decrease in the HCO_3^- concentration was detected. This phenomenon is attributed to accummulation of salts in the soils and rocks above the groundwater table during normal conditions and the flushing thereof due to extremely wet conditions. The present practice of over-irrigation in the area due to readily available Orange River water, could simulate similar flood conditions.

Introduction

During an investigation of the groundwater quality of the Great Fish River Basin in the Eastern Cape Province, water from a particular borehole on the farm Selection 132 at Baroda, 20 km northeast of Cradock, was sampled to determine the change in the groundwater quality with time. Over the period during which the samples were taken (February to March 1974), the area under discussion was, however, subjected to extreme flooding, thus disrupting the original aim of the exercise. This, however, led to the opportunity to study the effect of flood conditions on the groundwater quality of the borehole.

A mean rainfall of 55 mm during February and March was recorded for the area, whilst in the first week of March 1974, 217 mm of rain fell (Figure 2).

Prior to the introduction of Orange River water to the Great Fish River, very little water was available for irrigation in the area. Irrigation then was applied at long irregular intervals only when sufficient water was available in the Grassridge Dam or when some flood water was available in the river, after thunderstorms higher up in the basin. Viljoen and Liebenberg (1974) for example recorded an application of 36 mm of irrigation water to the area during one such a lead. Over-irrigation in the area, prior to the introduction of Orange River water therefore appears to have been unlikely, whilst the flooding conditions which then occurred could be regarded as over-irrigation when 217 mm of water were applied within one week.

Since the introduction of Orange River water, the irrigation practices in the Great Fish River Valley have changed dramatically. Irrigation is done fortnightly during the irrigation season (September to April) and much more water is applied, therefore increasing the possibility of over-irrigation.

The changes which took place in the groundwater quality of the area after the flood conditions in 1974, can therefore occur again as a result of over-irrigation or possible future flood conditions.

Description of borehole and sampling techniques

The borehole is located near irrigation lands, although (because of the lack of water) only 20 ha of land approximately 200 m to the west of the borehole were irrigated at the time of the investigation.

The borehole is near a dolerite dyke which has a north-south strike and is covered by 3 m of alluvium (Fig. 1). After the soil was penetrated, grey mudstone was encountered up to a depth of about 12 m. At this depth fractured mudstone in which the groundwater was located, was drilled up to 24 m when the dolerite was encountered. No groundwater was found in the unfractured mudstone. This observation is in agreement with that of Tordiffe (1978) who found the porosity of the mudstone in the area too low to contain any significant amounts of water and that most of the groundwater was located in joints and fracture zones in the rock. The groundwater level must therefore be regarded as a pisometric level rather than a continuous one (Wilke, 1962). This level varied between 9,8 m and 7,8 m below the collar height of the borehole during the investigation.

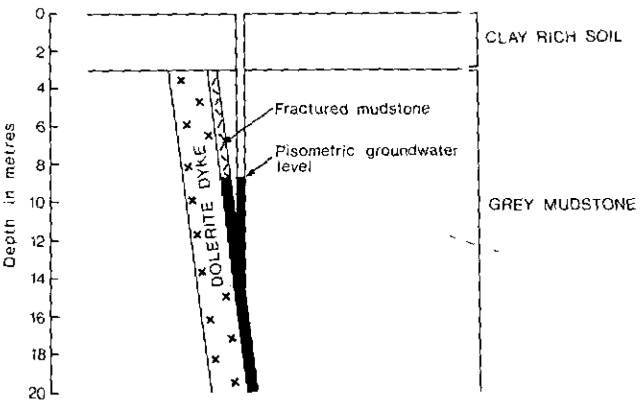

Figure 1
Schematic profile of borehole B93.

The soil overlying the mudstone consists of fine grained clay rich material, whilst at a depth of about 1 m calcarious nodules occur. Such soils are typical of semi-arid environments where insufficient water is unable to leach the salts from the soils, thus causing them to rather accumulate in a "closed" chemical system (Levinson, 1980).

The borehole is fitted with a standard pump which delivers 4 000 ℓ/h. Sampling commenced after 15 min of pumping.

Results and discussion

The samples collected were analysed for the major elements normally encountered in the groundwater of the area i.e. Na^+, K^+ Ca^{++}, Mg^{++}, Cl^-, $SO_4^=$ and HCO_3^- (Table 1).

TABLE 1
VARIATION IN THE CHEMICAL QUALITY OF THE GROUNDWATER IN BOREHOLE B93* WITH TIME (mg/ℓ)

Date	Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	HCO_3^-	$SO_4^=$	TDS
15-11-1973	320	3	150	96	475	355	445	1844
26-02-1974	260	4	120	70	460	362	280	1556
28-03-1974	290	–	110	70	430	309	345	1554
11-04-1974	420	–	110	100	696	272	410	2008
17-05-1974	215	–	73	51	300	271	200	1110
09-09-1974	216	4	114	58	370	309	220	1291

*Locality of borehole B93: Latitude S 32°00,4' and Longitude E 25°30,1'
– Below detection limit.

The results in Table 1 are graphically displayed in Fig. 2 which clearly reveals that Cl^- and Na^+ were respectively the dominating anion and cation in the groundwater and remained so over the entire time span during which the samples were collected.

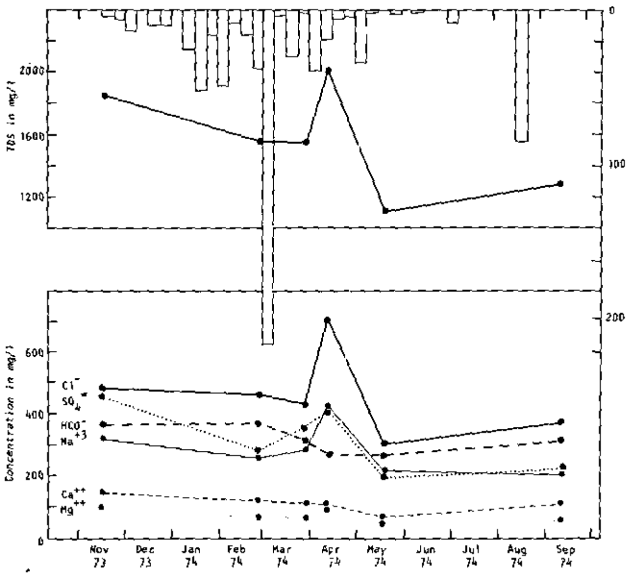

Figure 2
Chemical changes in the groundwater quality of a borehole near Cradock after extreme flooding. (Weekly rainfall data are inverted).

Initially the TDS decreased considerably from November to February. This was caused by decreases in the concentrations of $SO_4^=$ (37 %), Mg^{++} (27 %), Ca^{++} (20 %) and Na^+ (19 %), whilst Cl^- decreased by 2 %. Approximately 1½ months after the flood conditions which occurred during the first week in March, the TDS increased sharply and was caused by increases in Na^+, Cl^-, $SO_4^=$ and Mg^{++} which then had respective concentrations of 62 %, 51 %, 46 % and 43 % higher than in February. At the same instance the HCO_3^- and Ca^{++} concentrations respectively decreased by 25 % and 8 %. The next sample, collected one month later, showed a sharp decrease in the TDS which was caused by the following decreases in the concentrations of Cl^- (57 %), $SO_4^=$ (51 %), Na^+ (49 %), Mg^{++} (49 %), Ca^{++} (34 %) and HCO_3^- (0,49 %). The sample collected in September had a fair increase in all the dissolved substances, although apart from the Ca^{++}, the others showed no dramatic increases.

On comparing the changes which took place in the groundwater from November to February with those which took place after the flood conditions, it is clear that different mechanisms were responsible for these changes. This paper is however, concerned only with those changes which occurred after the flood conditions.

Conclusion

The sudden increase in the ions mentioned above leads the authors to believe that Na^+, Cl^- and $SO_4^=$ in particular, were trapped in the overlying clay-rich soils and in rock strata of the aerated zone above the groundwater table and that they were actually flushed to the groundwater table by the downward moving meteoric water.

Prior to the flooding event very little meteoric water reached the groundwater level, as this water was soon returned to the atmosphere by high evapotranspiration, resulting in the accumulation of soluble salts in the aerated zone.

Once these salts were leached due to the high infiltration, relatively fresh meteoric water followed, which in turn diluted the saline groundwater to such an extent that the TDS decreased to below the levels preceding the flood. Only after some considerable time did the quality of the groundwater revert to concentrations above those preceding the flood.

The importance of this observation is that, during periods of excessive application of water e.g. extreme rainfall or over-irrigation, salts in the soil are transported down to the groundwater level. This saline groundwater then reaches the river via the various points of discharge and can therefore present a hazard to the irrigation along the river. Soon after the above floods the water in Lake Mentz on the Sundays River, became so saline with Na^+ and Cl^- that it was unsuitable for irrigating the orange orchards in the Kirkwood area (Viljoen, 1983).

Acknowledgements

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